Reply to the comments of Eric Hunt

Thank you for giving me the opportunity to review this paper. Overall, this paper represented results from a well-research project, is well-written, and will make a very nice addition to the literature once it is revised. The figures are of excellent quality.

We thank Eric Hunt for his positive and constructive feedback on our manuscript. Below, we provide a first reply (in blue) to his comments (which are shown in black). A detailed reply, including some complementary analyses related to comments, will be provided after the editor's decision and once the first author is back from parental leave (10.05.2020).

The only major issue is the authors terminology of defining drought for soil moisture in absolute terms as opposed to as an anomaly. While opting to look at soil moisture as a % of available water content (putting a current observation in the context of field capacity and wilting point) is highly appropriate, many members of the drought community would take significant issue with saying anything under 30% AWC is drought, if that occurs more than 20% of the time for a given location and time period. However, what the authors are conveying in the paper is soil moisture stress, or perhaps more correctly- low enough soil moisture to cause significant water stress for vegetation, in the context of drought and flash drought formation. Therefore, I ecommend the authors consider changing the term "SM drought" to "SM stress". This would in no way reduce the importance of the article or the effectiveness of the message. Clearly in years like 2003, 2015, 2018, and 1991, SM drought was appropriate but in other years it may not be, especially for grid points where that is a common occurrence.

We fully agree that using the term "drought" for a phenomenon that might not be below normal contradicts the definition of drought. We gladly take over the suggestion and refer to low enough soil moisture to (likely) cause significant water stress for vegetation, hereafter referred to as "SM stress" for brevity reasons. To comply with the comments of #R1, we will make sure to carefully discuss assumptions related to the used definition. In addition, we can create a Figure complementary to Fig. 8 (i.e., Fig. 8b), to discuss how rare "SM stress" is for a certain DOY, i.e., which percentile value represents 30% AWC. Such figure might provide an informative comparison, as there can be quite a variability in what "below normal" means depending on time of year and location.

Another thing for the authors to consider is to look at the development time and see what percent of cases were more flash drought oriented (e.g., 25-40 days from start to) vs. a more traditional drought that develops more slowly. That could then be tied to the temperature and precipitation anomalies, in addition to what is already shown in Figure 7.

We will characterize:

- The percentage of droughts that were more flash drought oriented vs. more traditional. This can be connected to Fig. 6b (which shows the distribution of development times).
- The meteorological anomalies during the development of flash droughts vs. slower developing traditional droughts. This will be connected as suggested to Fig. 7.

We will further add a similar kind of analyses with development time starting once SM reached 70% AWC (related to your last specific suggestion).

Finally, please make it more clear in the methods that Socc is only for a particular year and grid point combination. This is implied in the article but more explicitly stating it will help the readers.

We will emphasize in section 2.4 that S_{occ} was derived for each individual grid cell and year.

Specific comments are as follows:

Line 39: List some examples of drought indices and their references

We will add a new sentence that lists some examples of drought indices relevant for this study. This list will include some of the commonly used (standardized) meteorological indices such as the SPI and SPEI as well as some agricultural drought indices such as the Soil Moisture drought Index (SMI) or the Evaporative Stress Index (ESI) (McKee et al., 1993; Samaniego et al., 2012; Vicente-Serrano et al. 2010; Anderson et al. 2007).

L52-54:There are indices (e.g., ESI) that account for both ET and potential ET.

We will introduce indices that include both ET and PET, such as the ESI, in this paragraph.

L65: As in future climate scenarios or forecasting of soil moisture at S2S?

We will clarify that future refers to climate change scenarios.

L71-72: Consider re-writing sentence on drought.

We will rewrite this sentence.

L82: Below normal precipitation?

We will clarify that in this case "below normal anomaly" refers to a below normal anomaly of different hydrometeorological variables.

L131: What does TRAIN stand for?

We will mention that TRAIN stands for TRAnspiration and INterception (evaporation) since these were the most important elements at the time the model was originally developed.

L156: Please clarify the length of spin-up time for the model? Was it truly 1 year (1988) or all 31 years and only 1989-2018 considered in the analysis? If the former, you will need to provide justification for doing so.

The spin-up time of the model was 1 year, i.e., we started the simulations 1 year prior to the considered period. This was mainly done to get the initial condition with regard to snow right at the beginning of simulations. A longer spin-up time was not needed in this case, as within the study region there is no multiyear snow accumulation and the considered agricultural grid cells reach field capacity before the start of the new growing season. Further, a comparison with longer spin-up times (1984-1988) reveals that results are not affected by this.

L177: Elaborate further on why you chose to use FC as opposed to an AWC of say above 0.70.

This is an interesting remark. We use FC as it is a nice absolute quantity, i.e., from here SM started to deplete. However, we could definitely characterize the development starting from e.g. 70% AWC, which would be closer to the transition from no stress towards stress. Such an additional analyses could be integrated in quite a straightforward manner in Fig. 6 and possibly also in a modified Fig. 7 (see reply to second comment).

References:

Anderson, M. C., Norman, J. M., Mecikalski, J. R., Otkin, J. A., and Kustas, W. P.: A climatological study of evapotranspiration and moisture stress across the continental U.S. based on thermal remote sensing: 2. Surface moisture climatology, J. Geophys. Res., 112, https://doi.org/10.1029/2006JD007507, 2007.

McKee, T. B., Doesken, N. J., and Kleist, J.: The relationship of drought frequency and duration to time scale, in: 8th Conference on Applied Climatology, 17–22 January, Anaheim, California, American Meteorological Society, Boston, 179–184, 1993.

Samaniego, L., Kumar, R. and Zink, M.: Implications of Parameter Uncertainty on Soil Moisture Drought Analysis in Germany. J. Hydrometeorol., 14, 47–68. https://doi.org/10.1175/jhm-d-12-075.1, 2012.

Vicente-Serrano, S. M., Beguería, S. and López-Moreno, J. I.: A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index, J. Climate, 23, 1696–1718, https://doi.org/10.1175/2009JCLI2909.1, 2010.